CONCLUSIONS

Good winter and early spring subsoil moisture indicates a good cotton season; but unfavorable condition during growing season, such as violent monthly rainfall change from wet to dry, continuous heavy to excessive rains, with resulting poor cultivation and heavy weevil infestation, may easily offset the early advantage. A cold winter tends to destroy the hibernating insects and cut down the spring emergence; this favorable cotton factor, however, may be offset by late planting and a moist cool growing season, favoring the rapid multiplication of pests at a time when they will do the greatest harm to the delayed crop. On the contrary the disadvantages of a dry, abnormally warm winter or a late cold or extremely wet spring may be largely compensated for by later exceptionally favorable weather conditions.

Other things being equal, the ideal year for cotton would be one in which there was good soil-moisture storage during the preceding winter, which should be sufficiently cold to destroy the hibernating pests; followed by an early spring of moderate rainfall, promoting planting and cultivation of crop; a moderately dry, hot summer, with abundant sunshine, but not really droughty and not subject to sharp reversals in rainfall or temperature, thus favoring care and growth of crop and holding down weevil (this condition would favor certain other insects, however, of less serious nature). Finally, a fairly dry, bright autumn and late frost, to remove all of the cotton from the fields without deterioration or loss.

The vast area of Texas greatly complicates the study of weather and cotton yields. Within the State's borders, we have the semitropical climate of the lower Rio Grande Valley and the rigorous Temperature Zone climate of the Panhandle; the 50-inch annual rainfall of the lower Neches and Sabine Rivers in the southeast to the 10-inch rainfall of the extreme west; the long, flat reaches of the Coastal Plain to the high cap-rocked Llano Estacado and the rugged Trans-Pecos region.

Through the wide reaches of the State from the marine climate of the coast to the continental climate of the interior, there seems to be a persistent tendency toward zonal rainfall, i. e., for heavy precipitation to occur along the coast or paralleling it, even for hundreds of miles inland, materially affecting the average moisture over the State, and yet remaining more or less localized. While this fact is known, in a general review like this present study it is impracticable to enter into a discussion of these more specialized conditions, which often complicates the whole study, and deserves and should receive a careful analysis as to causes, locations, and frequency.

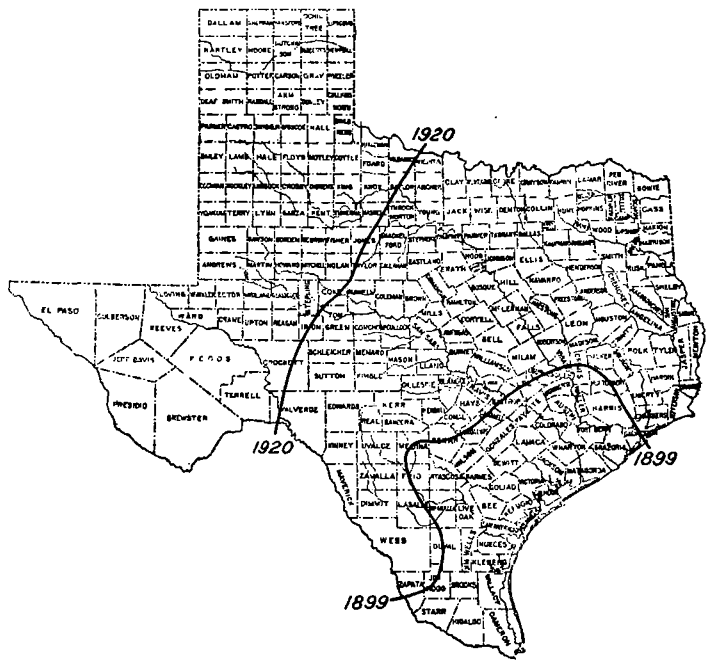

FIGURE 1.—Spread of Mexican cotton-boll weevil 1899–1920. Not much advance since 1920

For further study on weather and agriculture in general see Department of Agriculture Yearbook, 1924, pages 457 to 558, inclusive, by A. J. Henry, J. B. Kincer, H. C. Frankenfield, and W. R. Gregg, of the Weather Bureau, B. B. Smith, Bureau of Agricultural Economics, and E. N. Munns, Forest Service; Climatic Factors in the Agriculture of Louisiana and Southern Mississippi by W. F. McDonald, Weather Bureau, New Orleans.

RELATIONS BETWEEN SUMMERS IN INDIA AND WINTERS IN CANADA[1]

551.58 (71) (54)

By FRED GROISSMAYR

(Passau, Germany, September, 1929)

The weather elements of Argentina, Egypt, and especially East India are of enormous influence upon the following Canadian winters, nine months to three months later, as the correlation table distinctly shows:

Δt XII–II Winnipeg, Manitoba, 1877–1878 to 1920–1921

Correlations with preceding elements:

Argentina	Egypt	India
Goya: Δt I-VII:+0.55 ΔN IV:+0.51	Nile VII–X at Assuan−0.50	Δp I-X Nagpur+0.74 Δt VII-X India+0.73 ΔN I-X India −0.56

t = temperature, p = pressure, N = precipitation, I–XII = months, Δt VII–X India = (Cochin + Madras)/2; ΔN I–X India = (Jaipur + Nagpur + Allahabad + Masulipatam + Waltair)/5. Uniting Goya January–July temperatures and the three Indian weather elements, I have obtained the following:

Winter temperature forecasting formula for Winnipeg: Δt XII–II Winnipeg = 0.13 Δp I–X Nagpur + 2.6 Δt VII–X India − 0.13 ΔN I–X India + 0.85 Δt I–VII Goya.

These four elements give a total correlation of, $r = 0.81$ with Δt XII–II Winnipeg; the computed values (de-

[1] Much of the preliminary work on which this note is based is described in a previous paper published in the May, 1929, issue of *Meteorologische Zeitschrift* under the title "Der Einfluss der Wetterfaktoren Indiens auf den Folgewinter Kanadas." See abstract and excerpts on following pages.—*Editor.*

partures) in case of this formula agree very well with the actual ones, as the following table shows:

[C=computed, a=actual, 1877=winter of 1877–1878]

	C	a		C	a		C	a
1877	+10.8	+17.9	1892	−9.9	−7.7	1907	+3.8	+9.1
1878	−1.4	−2.9	1893	−3.9	−4.6	1908	−0.1	+1.5
1879	−6.6	−6.6	1894	−5.4	+1.2	1909	−1.0	+1.1
1880	−4.0	−4.2	1895	−1.0	+2.2	1910	−4.2	−0.3
1881	+0.8	+3.3	1896	+2.1	+2.2	1911	+2.6	+1.4
1882	−5.6	−8.3	1897	+0.8	+3.1	1912	+2.6	+0.6
1883	−4.9	−9.1	1898	−2.0	−3.6	1913	+3.8	+4.9
1884	−1.9	−9.1	1899	+5.9	+2.6	1914	+4.7	+4.3
1885	−0.8	−3.4	1900	+4.6	+0.9	1915	+1.6	+0.9
1886	−6.4	−10.0	1901	+3.8	+8.0	1916	−4.2	−5.3
1887	−7.7	−7.1	1902	+5.0	+2.1	1917	−3.7	−3.4
1888	+0.7	+3.4	1903	−1.5	−4.0	1918	+8.7	+8.3
1889	−2.2	−5.1	1904	+1.8	−0.2	1919	+4.3	+0.2
1890	−5.1	+3.4	1905	+6.1	+5.7	1920	+6.1	+8.8
1891	+3.4	+1.3	1906	+1.0	−2.7			

C and a are given in Fahrenheit degrees; Δp I–X Nagpur = mean monthly pressure departures in thousandths of an inch, therefore, for example, 0.020 = 20; Δt VII–X India = °F.; ΔN I–X India = inches.

The excessively mild winters of 1877–78, 1901–2, 1905–6, and 1918–19 were preceded by severe droughts in India.

For extreme western Canada also I obtained excellent results in a similar case. For this research I combined the four stations (Edmonton + Calgary + Qu'Appelle + Prince Albert)/4, using the 36-year period, 1885–1920, inclusive. For the winters of 1885–86 to 1920–21, inclusive, the prediction formula is given by the following equation:

$$\Delta t \text{ XII–II Saskatchewan and Alberta} = 0.043\,\Delta p \text{ VIII–X Nagpur} + 0.94\,\Delta t \text{ VI–VIII Madras} - 0.25\,\Delta N \text{ I–X India}$$

Correlations:

$$\left.\begin{array}{ll}\Delta p \text{ VIII–X Nagpur} & +0.62\\ \Delta t \text{ VI–VIII Madras} & +0.62\\ \Delta N \text{ I–X India} & +0.72\end{array}\right\}\ \text{Total correlation} = 0.75$$

Agreements of C and a (years in which $C \geqq \pm 3°$ F.).

	C	a		C	a
1886	−5.8	−10.6	1907	+3.1	+8.2
1889	−3.4	−9.8	1910	−4.0	−3.9
1892	−6.8	−4.7	1911	+3.1	+1.9
1893	−4.7	−4.0	1913	+3.6	+4.0
1894	−4.1	−2.0	1916	−5.4	−5.9
1896	+4.7	+1.1	1917	−7.3	−6.1
1899	+5.8	+0.8	1918	+5.9	+6.9
1903	−3.8	−1.8	1920	+4.3	+5.7
1905	+3.7	+7.0			

Here we find agreement in respect to plus or minus of a and C in all cases for which $C \geqq \pm 3°$ F.; very close is the influence of Indian rainfall in all the years in which the *mean* departure of rainfall sum (January to October) was $\geqq \pm 4$ inches (per *one* of these five Indian stations); the following winter in Saskatchewan and Alberta had the contrary character.

	1886	1887	1888	1889	1892	1893	1894	1896	1897	1898	1899	1901
N	+7	+4	−4	+4	+15	+8	+11	−11	−6	+5	−12′	−4
t	−10.6	−6.1	+6.8	−9.8	−4.7	−4.0	−2.0	+1.1	+2.2	−2.1	+0.8	+6.7

	1902	1903	1905	1907	1910	1911	1913	1915	1916	1917	1918	1920
N	−4	−4	+5	−7	−8	+5	−7	+6	+11	14	−13	−6
t	+1.4	−1.8	+7.0	+8.2	−3.9	+1.9	+4.0	−2.7	−5.9	−6.1	+6.9	+5.7

Accidental? Never! The diagram of winter temperature departures (fig. 1) shows the close parallelism of the actual and the computed data.

DISCUSSION

(Clark University, Worcester, Mass., November 24, 1929)

The extraordinarily high correlation found by Mr. Groissmayr between pressures, temperatures, and rainfall of certain tropical regions and the later winter temperatures in the interior of Canada challenges North American meteorologists (1) to test Mr. Groissmayr's claims by applying his formulas to the years after the period he used in making it, (2) to study the physical basis for such a correlation, and (3) to explore other possibilties not only for predicting winter mean temperatures but also for other seasons and for all parts of the continent.[1]

As a beginning, I submit the following computations, according to Mr. Groissmayr's formulas, for the six winters, 1920–1926 (the first one being the last in the

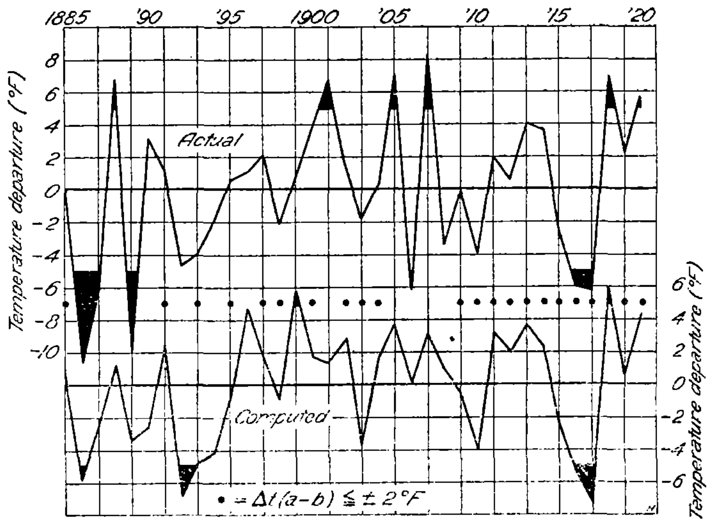

FIGURE 1.—Graph of actual and computed temperature departures in Canada, 1885–1920

long period of years used by him), and what the formula seems to indicate for the winter of 1929–30.

Winter mean temperature departures °F

	Winnipeg			Saskatchewan and Alberta		
	Computed		Actual	Computed		Actual
	Official	Clayton		Official	Clayton	
1920–21	+7.0	+7.2	+9.2	+4.1	+4.2	+6.2
1921–22	−1.8	−0.8	+4.3	+1.4	+1.5	−0.1
1922–23	+1.0	+2.0	+1.1	+2.8	+2.9	−0.5
1923–24	+1.2	+2.9	+8.1	+3.7	+3.8	+6.8
1924–25	−2.1	−0.5	−0.1	+0.6	+0.7	−3.0
1925–26	[a] +0.1	[1] +0.9	+9.0	−0.5	−0.4	+12.2
1929–30	[b] +0.6	[2] +1.4	....	[1] +1.6	[2] +1.4	....

[a] Goya term omitted. [b] October data omitted.

For 1920–21, neither the computed nor the actual departures of winter temperature correspond exactly to Mr. Groissmayr's figures, though they are nearly the same. In the first column, "Official," I used simply the departures as published in official reports, in the

[1] *Cf.* Groissmayr's tropical indicators for autumn temperatures in the eastern United States, Monthly Weather Review, July, 1926, 54: 299; January, 1929, 57; 20–21.

second, "Clayton," I used Clayton's World Weather Records, as, apparently, Mr. Groissmayr had, and obtained, my departures from the Clayton normals, except for 1929 Goya temperatures, when only the departures were available in the Argentine "Resumen Mensual."

Of the 44 winters used by Groissmayr for Winnipeg, the calculated and actual departures were the same in 37, or 84 per cent. The additional five winters show similar correspondence. Droughts in India preceded five of the six warm winters in Groissmayr's series, but only one of the two warm winters in the new series.

In view of the shorter period of years, 36, for Saskatchewan and Alberta, Mr. Groissmayr gives only the larger indications, and shows that for computed departures $\geqq \pm 3°$ F. there is *invariable* agreement of the subsequent winter temperature as to sign. In the new series, the one strong indication of a warm winter was likewise verified.

In the 24 years when India was unusually wet or dry, Groissmayr shows that Saskatchewan and Alberta winters have been, *without exception,* below or above normal in temperature. The year 1922 (January to October) averaged 6 inches below normal and 1925 averaged 6 inches above normal; the following winter temperatures were, respectively, below normal and above normal, breaking the rule. Two-thirds of the excess of rainfall in 1925, however, occurred at but one of the five stations and in a single month.

If the forecasting formula had been applied for the five winters 1921–1926 and the results published in advance of each winter, the forecasts and verifications would have run about as follows:

1921–22: A winter of normal temperature is indicated, possibly slightly below normal in Manitoba and above normal in Saskatchewan and Alberta. Verification: A moderate degree above normal in Manitoba and normal in the other prairie Provinces. *Reasonably successful.*

1922–23: A winter temperature slightly above normal is indicated, with a little greater departure in Saskatchewan and Alberta than in Manitoba. Verification: A little above normal in Manitoba and just under normal in the other Provinces. *Reasonably successful.*

1923–24: A mild winter is indicated, especially for Saskatchewan and Alberta. Verification: Very mild throughout. *Nearly perfect.*

1924–25: A winter of normal temperature is indicated. Verification: Normal in Manitoba, a little below normal in Saskatchewan and Alberta. *Good forecast.*

1925–26: A normal winter is indicated, possibly slightly above normal in Manitoba. Verification: Extremely mild throughout. *Poor forecast.*

In five years: One nearly perfect, two reasonably successful, one good and one poor.

According to criteria published two years ago [2] we may say that this performance is within the limits of being satisfactory for official presentation to the public, and, therefore, that if the winters of 1926–1930 do as well as those of 1921–1926, the physical connections here indicated should be investigated.

THE INFLUENCE OF THE WEATHER FACTORS IN INDIA ON THE FOLLOWING WINTER IN CANADA

By FRED GROISSMAYR, Passau, Germany

(Abstract and excerpts by C. F. Brooks; translation by W. W. Reed, of "Der Einfluss der Wetterfaktoren Indiens auf der Folgewinter Kanadas." *Met. Zeitschr.*, May, 1929, 46:176)

Following the lead of E. W. Bliss,[1] who gives four somewhat useful correlation coefficients indicating winter temperatures for central North America from previous conditions about the Indian Ocean, the author sought higher correlations by adding more tropical elements and localizing the North American end. The factors used by Bliss were pressure at Mauritius, temperature at Batavia, the Nile flood, and Indian rainfall. Since Schostakowitsch had found that over the Indian-Australian region temperature and pressure varied together while precipitation went opposite, the author added Indian temperature and pressure and Batavia and Egypt pressures, and also weather conditions of Argentina, which has long association with other Indian monsoon indicators.

"For the whole area investigated [in central North America] the pressure and temperature of India prove more influential than the monsoon rains of northwest India. With the exception of Montreal, the pressure over central India is more closely connected with the winter temperature of the region under consideration than is the summer of south India. Especially close relations resulted for the winter in Manitoba; also the autumn temperatures of Bombay, and that of Labore plus Allahabad show uncommonly close correlation with the character of the cold season at Lake Winnipeg."

1876–1920: Δt IX–XI Allahabad plus Lahore with Δt XII–II Winnipeg: r=0.62.

1878–1920: Δt IX–XI Bombay with Δt XII–II Winnipeg: r=0.66.

After an especially cool autumn —2° F. or more below normal—in northwest India there always followed a severe winter at Winnipeg, and after a warm autumn—2° above—a relatively mild winter.

	1876	1877	1879	1884	1896	1907	1917	1920
Δt IX–XI Allahabad and Lahore	−2.0	+2.5	−2.0	−2.6	+2.7	+2.5	−2.7	+2.6
Δt XII–II Winnipeg	−0.8	+17.9	−6.0	−9.1	+2.2	+9.1	−3.4	+8.8

Such decided relations led to further study of tropical factors with respect to Winnipeg's winters and to the discovery of the additional very notable correlation coefficients: With Nile flood, at Assuan, 1873–1922, $r = -0.52 \pm 0.07$; with Batavia October pressure departure, 1873–1922, $r = +0.54 \pm 0.07$; with Batavia October and November temperature departure, $r = +0.60 \pm 0.06$, and with Goya, Argentina, temperature departure April to July, $r = +0.52 \pm 0.07$. Pressure over central India proved most closely correlated with the subsequent winter at Winnipeg, especially when advantage was taken of the pronounced tendency of weather in the tropics to maintain an existing departure.

The mean monthly pressure departure at Nagpur from January to October is correlated with the departure of the winter temperature of Canada and of the north central part of the United States, the coefficient for Winnipeg being, $r = +0.77 \pm 0.04$, "the highest correlation ever

[1] E. W. Bliss, World Weather III, Memoirs, Quar. Jour. Roy. Metl. Soc., vol. II, No. 17, — pp.

[2] Charles F. Brooks, Performance in Long-range Forecasting. MONTHLY WEATHER REVIEW, September, 1927, 55:390–395, including bibliography.